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Development of 100W-class Loop Heat Pipes for Space Use and On-orbit Experiment Test Plan

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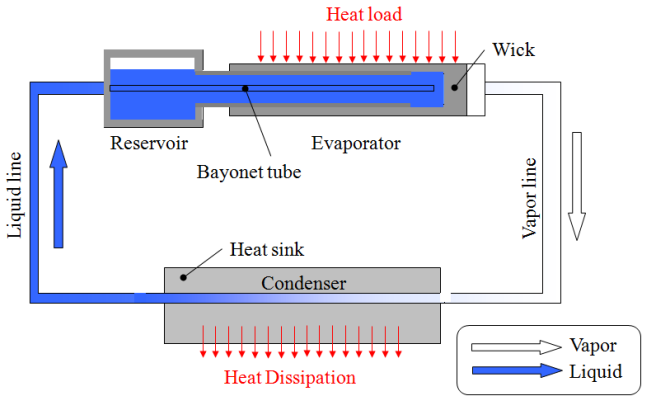
Outline

- Motivation and Objective
- Overview of the development of LHPs in JAXA
- Development of BBM
  - BBM specifications
  - Ground testing in ambient
    -- Start-up and step-wise power test
    -- Power cycle test
    -- Condenser sink temperature change test
- On-orbit experiment test plan
- Summary

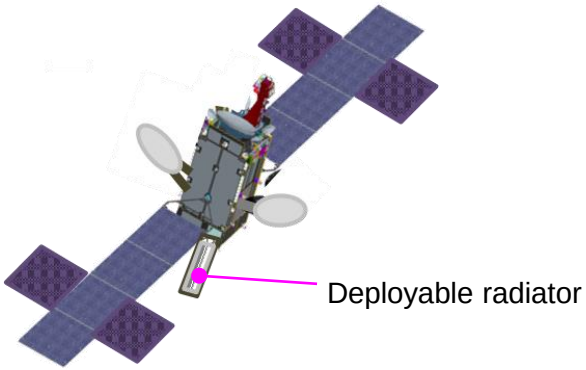
Motivation and objective

Development of LHPs has been conducting

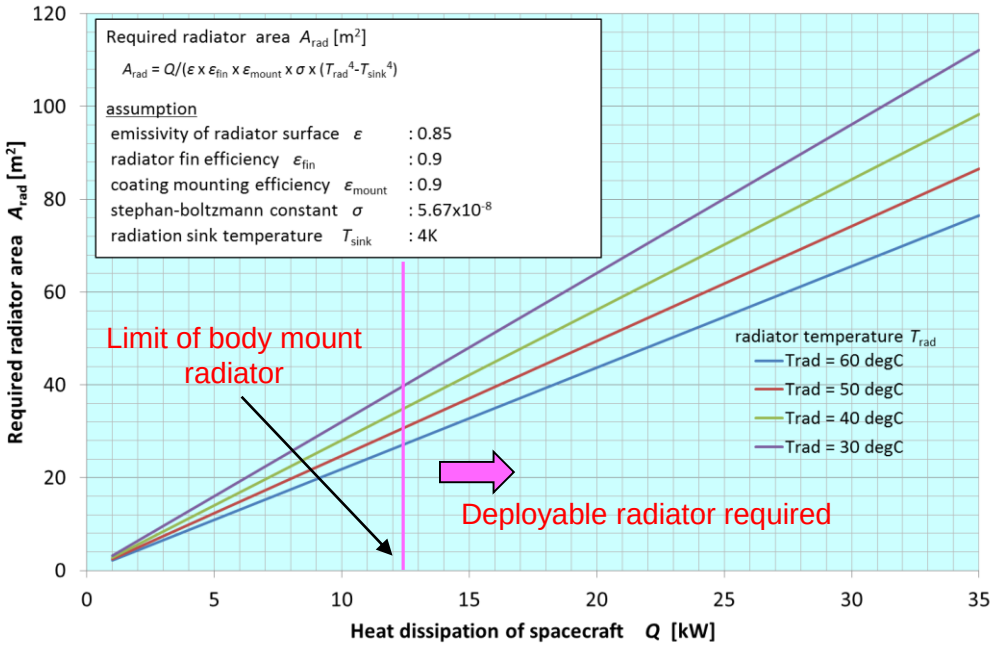
- to meet the wide variety of requirements which can not be met with only existing thermal control technology (e.g. temperature control with high accuracy, shut down operation)
- to realize the LHP-based deployable radiator for near future high heat generation spacecraft bus



Schematic of LHP



Spacecraft bus with deployable radiator



Heat dissipation of spacecraft vs required radiator area

Overview of the development of LHPs in JAXA

Research and development of two types of LHP has been conducting.

Reservoir embedded LHP (RELHP)

+ Reservoir is embedded in the evaporator core.
+ This type of LHP is in the space demonstration phase.
+ On orbit experiment of a deployable radiator using this type of LHP has been conducting.

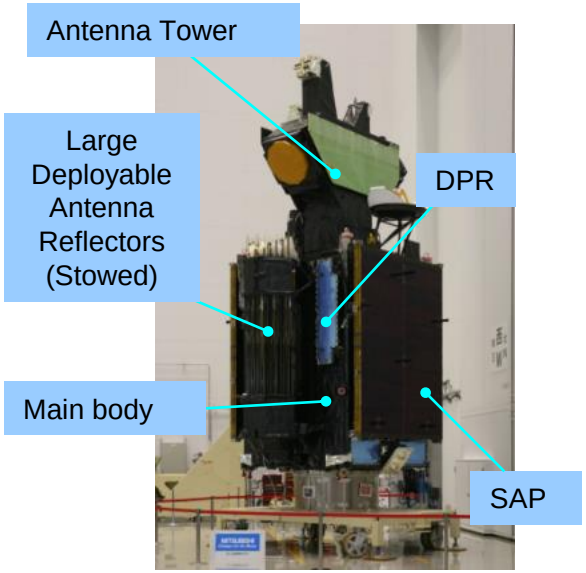
Normal LHP

+ This type of LHP is in BBM phase.
+ BBM was designed and manufactured → Main topic of this presentation
  to acquire the design technique
  to acquire the manufacturing technology
+ Visualization of working fluid using neutron radiography was also conducted
  to understand the LHP operation
  to acquire the data for improvement of LHP modeling and design
+ On-orbit experiment on ISS is planned in 2016. → Main topic of this presentation

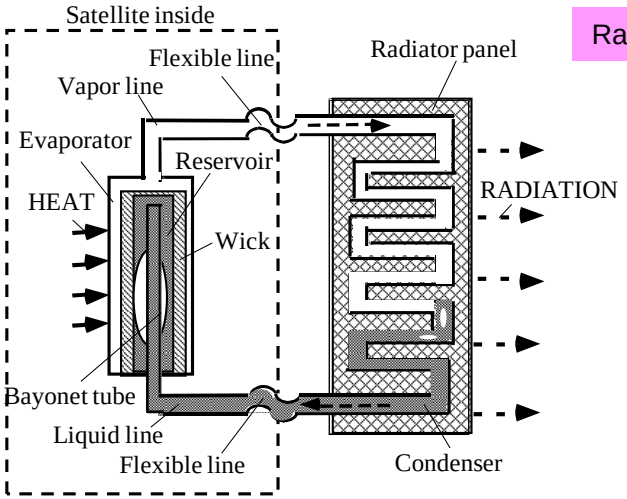
Overview of the development of LHPs in JAXA (Cont.)

RELHP and On-orbit experiment of RELHP based deployable radiator

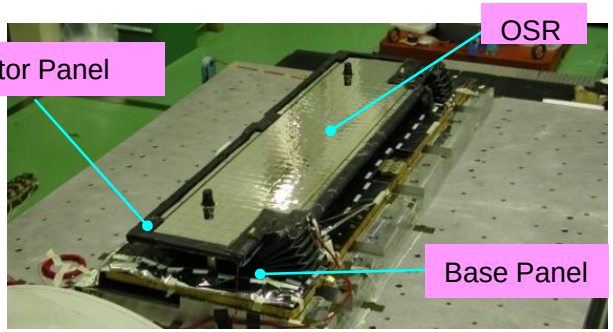
RELHP based Deployable Radiator (DPR) was installed on Japanese satellite KIKU-8.
KIKU-8 was launched by H-II rocket in 2006 and on-orbit experiment has been conducting.



KIKU-8



Schematic of DPR



Deployable Radiator (DPR)

Evaporator (O.D.: ϕ39.5mm, L=1000mm)

LHP showed good performance on orbit.
No degradation of LHP was confirmed during three years after the launch.
We are ready to apply this type of LHP to the practical mission.

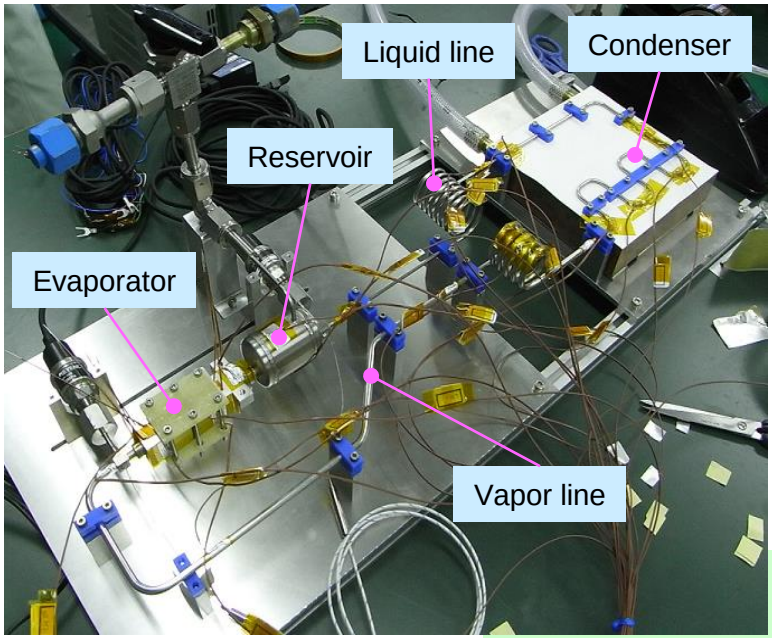
Overview of the development of LHPs in JAXA (Cont.)

Development of Normal LHP

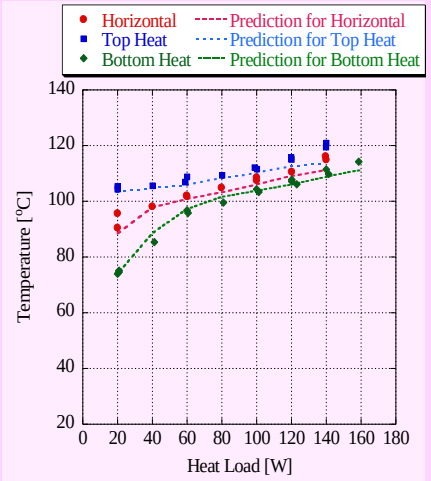
Development of H/W and numerical simulation model has been conducting.
As part of the study, visualization of working fluid using a neutron radiography was conducted.
Based on these activity, BBM was designed, fabricated and tested.

Primary wick

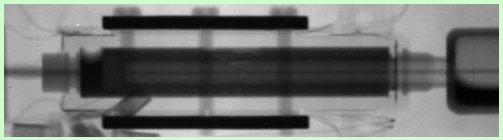
Secondary wick



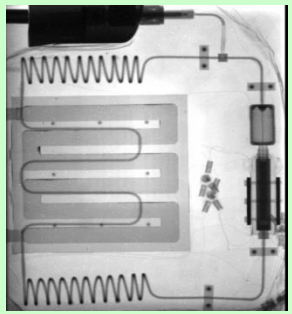
Laboratory model



Development of simulation model
(Comparison between test data and prediction)



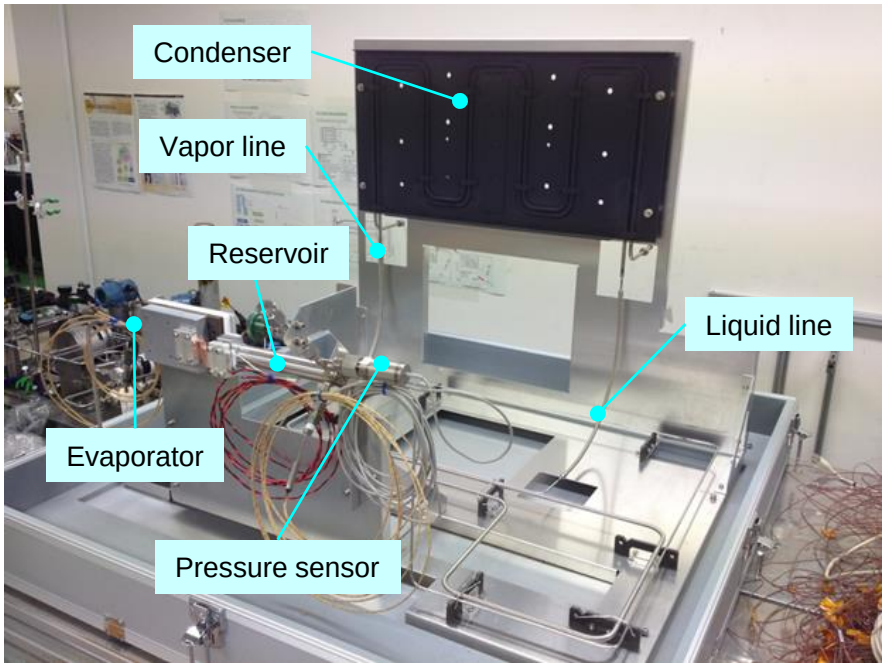
Visualization of working fluid
by neutron radiography



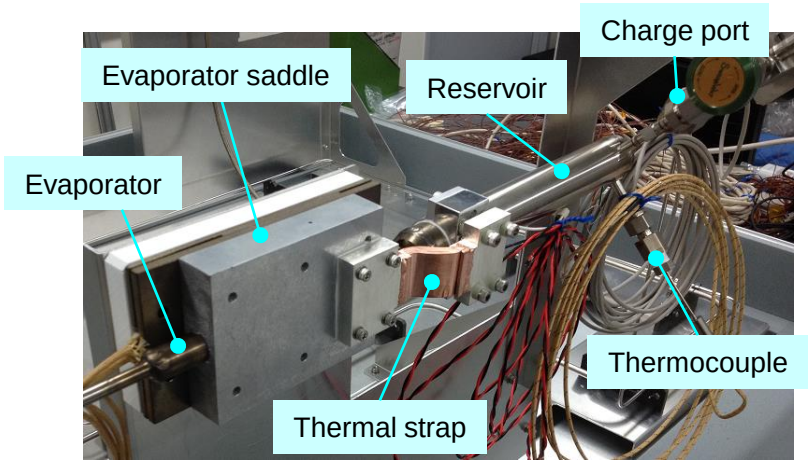
Development of BBM

◆BBM specifications

100W-class ammonia LHP



Appearance of BBM



Close-up view around Evaporator/CC

Major specifications of BBM

Evaporator	O.D.:12.7mm, Length:10cm
Primary Wick	Sintered stainless steel Pore radius: 0.95-1.2um Permeability: 2.8 x $10^{-13}m^2$ Porosity: 64%
Vapor line	I.D.:4.57mm, Length:3m
Condenser line	I.D.4.57mm, Length:1.8m
Liquid line	I.D.2mm, Length:3m
Working Fluid	Ammonia

Development of BBM (Cont.)

◆**Tests performed in ambient**

- Step-wise heating test
- Power cycle test
- Condenser sink temperature cycle test
- Start-up test at low heat load
- High heat load test
- Tilted orientation test
- Shut-down test
- Operating temperature test
- Forced start-up test

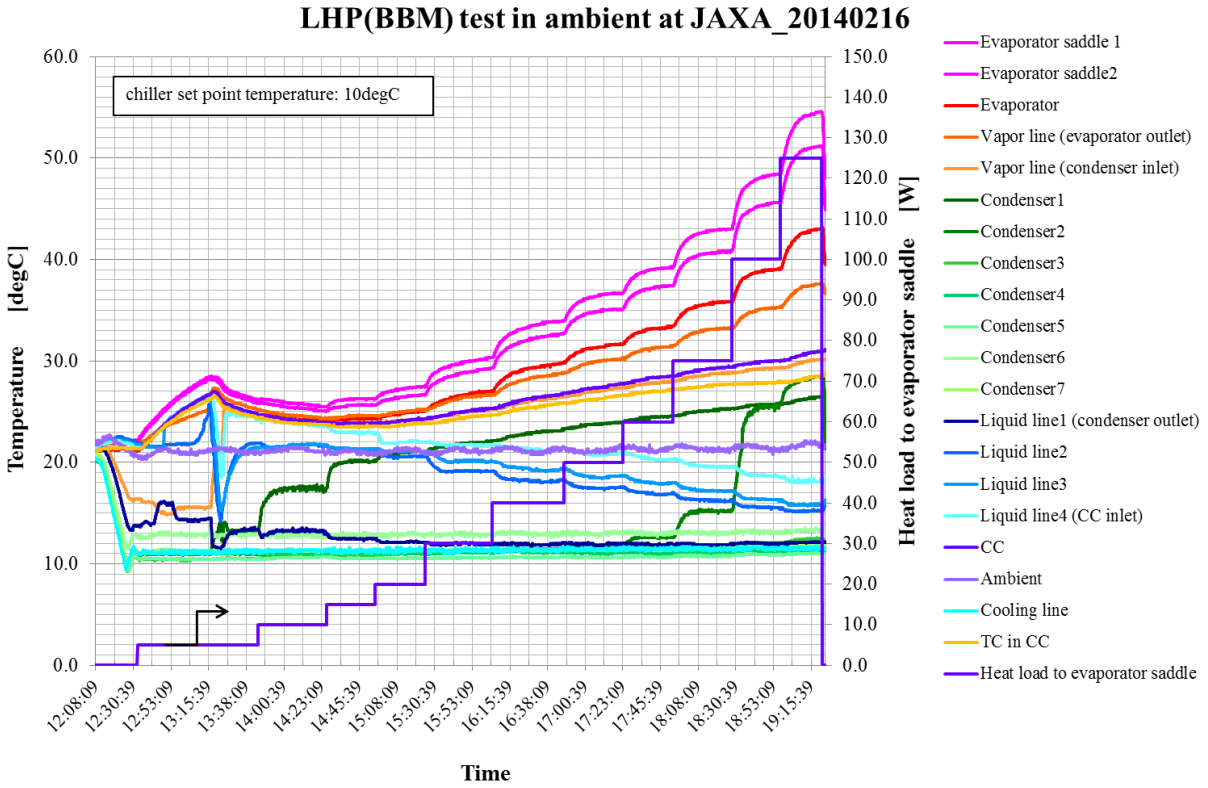
Development of BBM (Cont.)

◆Ground testing of BBM in ambient

-- Start-up and step-wise power test

heat load: 5W → 10W → 15W → 20W → 30W → 40W → 50W → 60W → 70W →80W → 90W → 100W → 125W

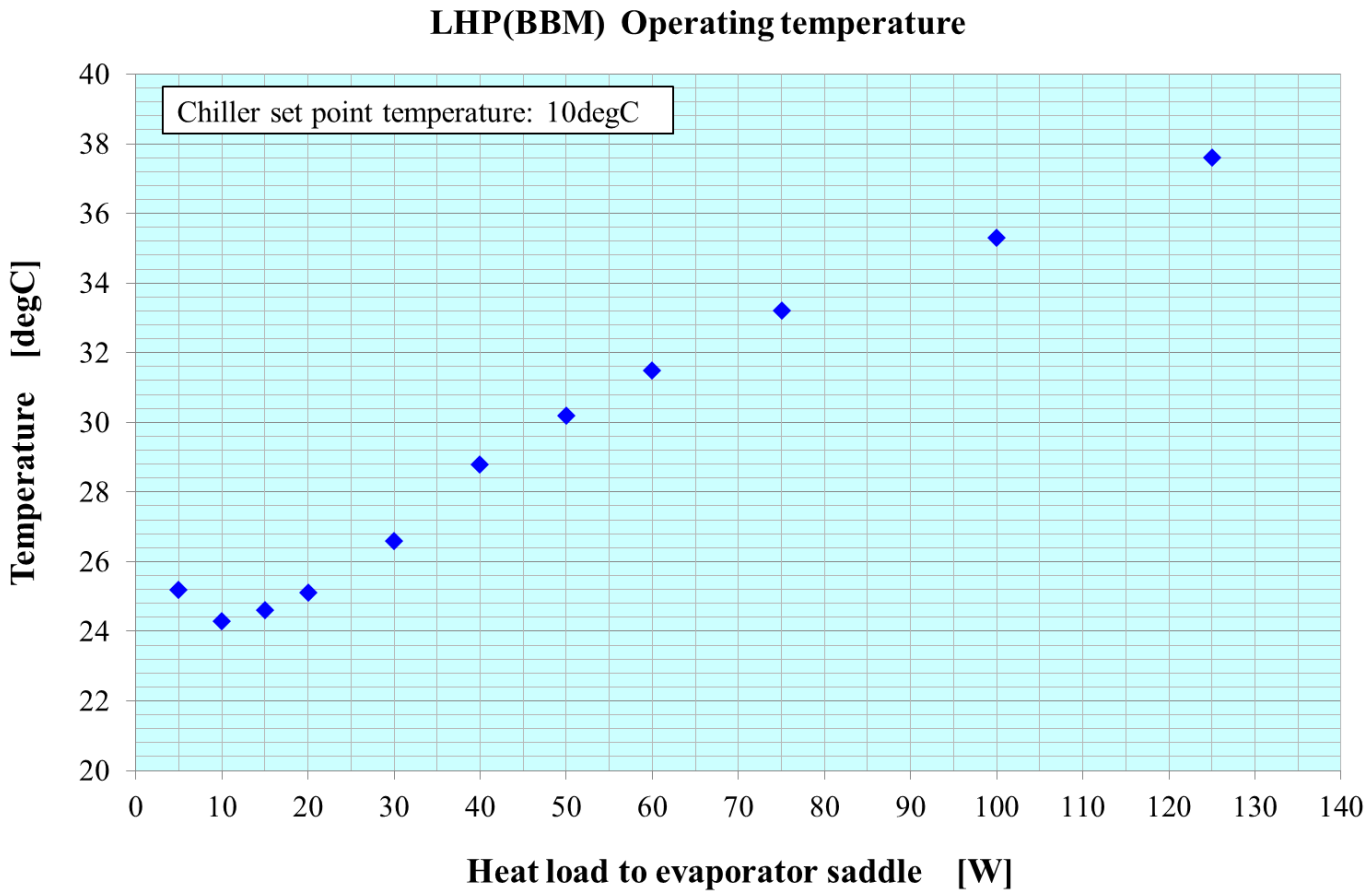
condenser sink temp. : 10degC



BBM successfully started up at heat load 5W and showed very stable behavior up to 125W.

Development of BBM (Cont.)

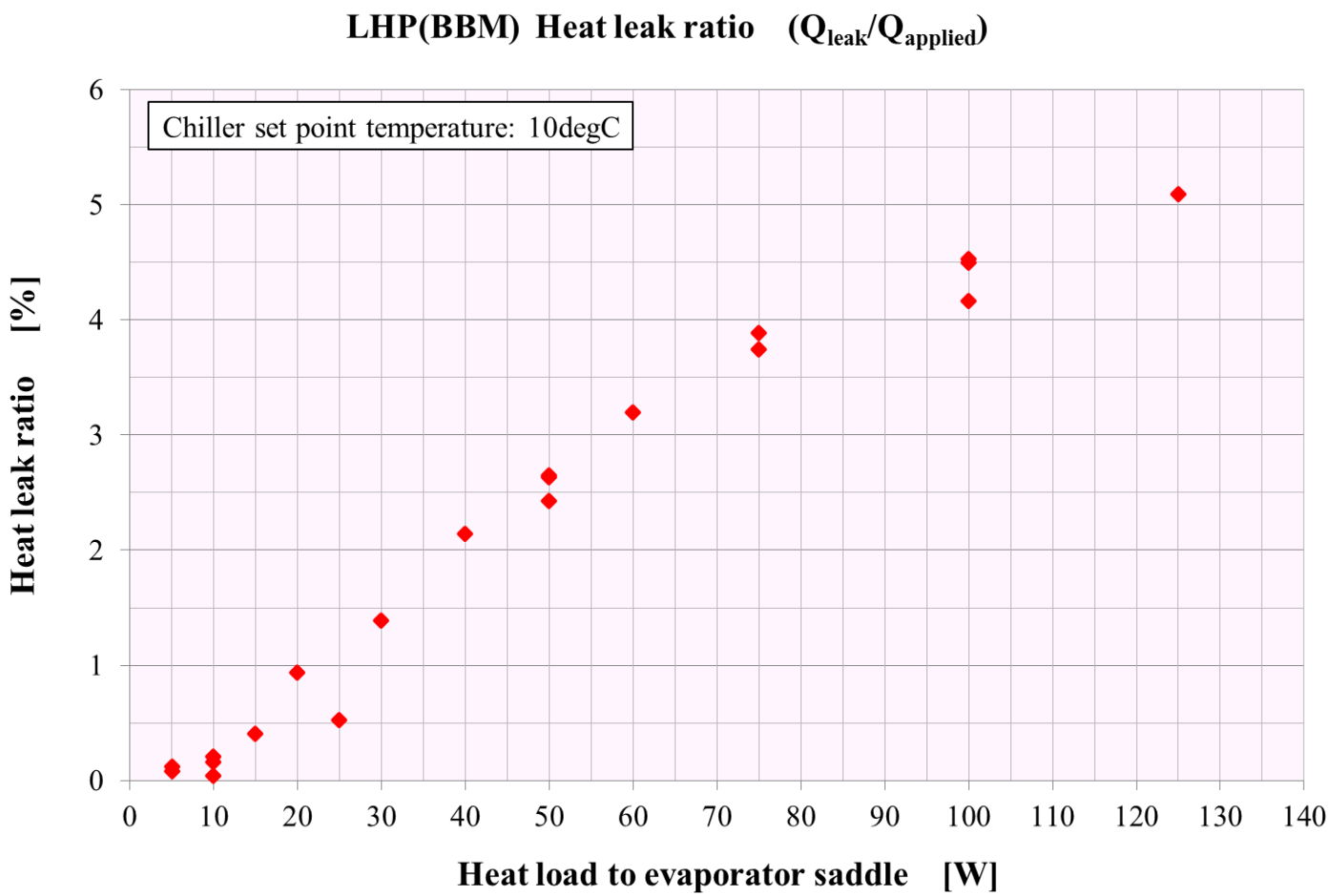
◆**Ground testing of BBM in ambient**



Operating temperature vs heat load to evaporator saddle
(chiller set point temperature: 10degC)

Development of BBM (Cont.)

◆Ground testing of BBM in ambient



Heat leak ration (heat leak to reservoir / heat load to evaporator) vs heat load to evaporator saddle

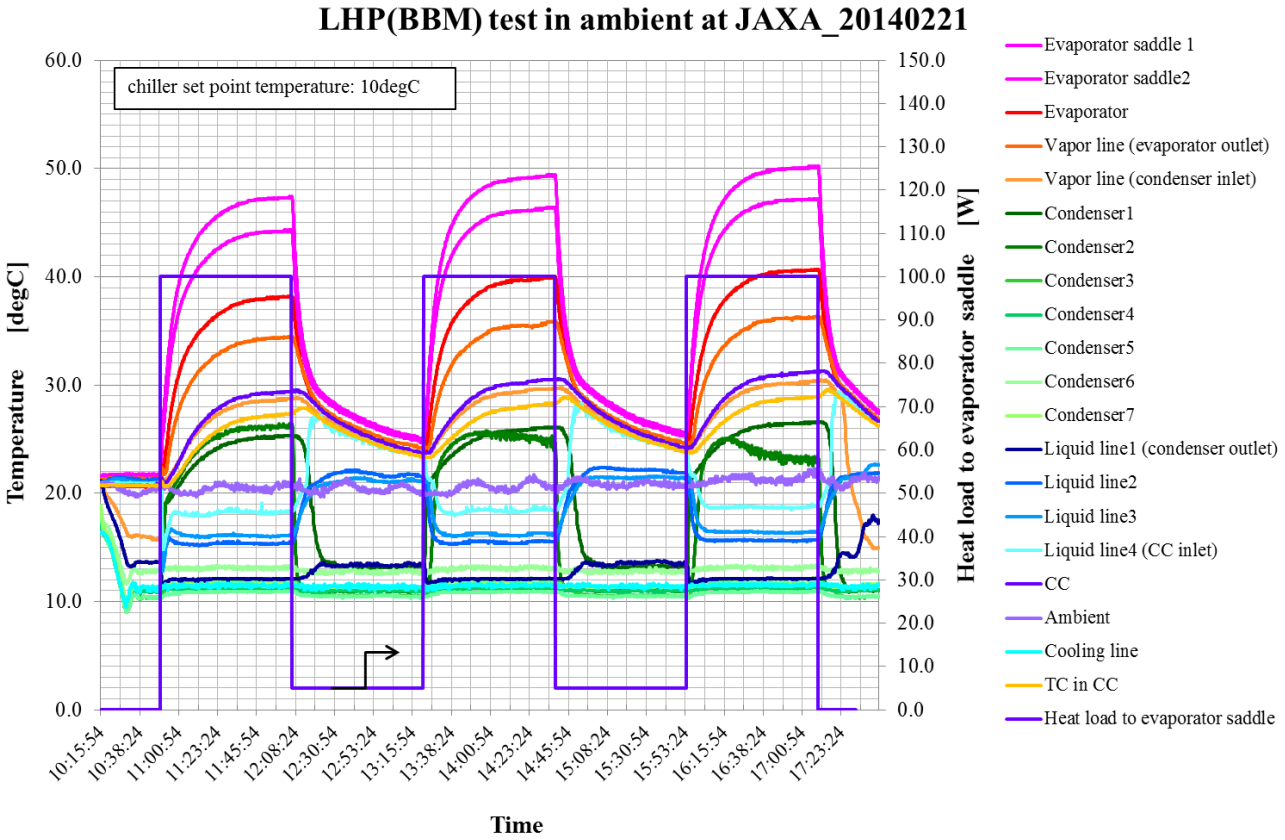
Development of BBM (Cont.)

◆Ground testing of BBM in ambient

-- Power cycle test

heat load: 100W → 5W → 100W → 5W → 100W

condenser sink temp. : 10degC



LHP showed stable behavior in sudden change in heat load to the evaporator.

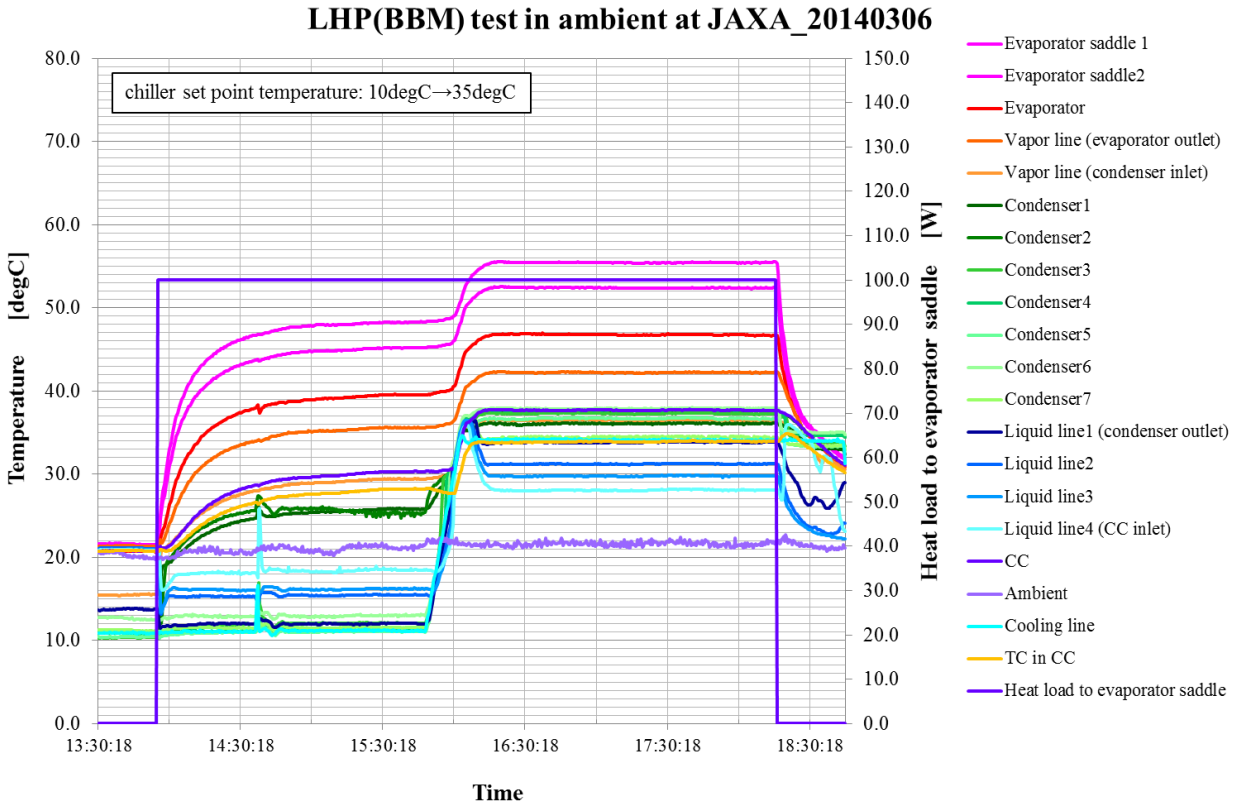
Development of BBM (Cont.)

◆Ground testing of BBM in ambient

-- Condenser sink temperature change test

heat load: 100W constant

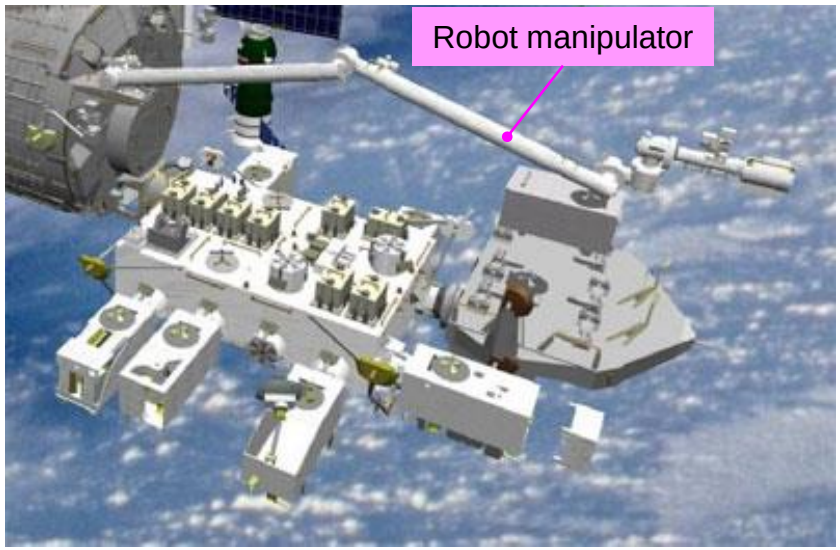
condenser sink temp. : 10degC → 35degC



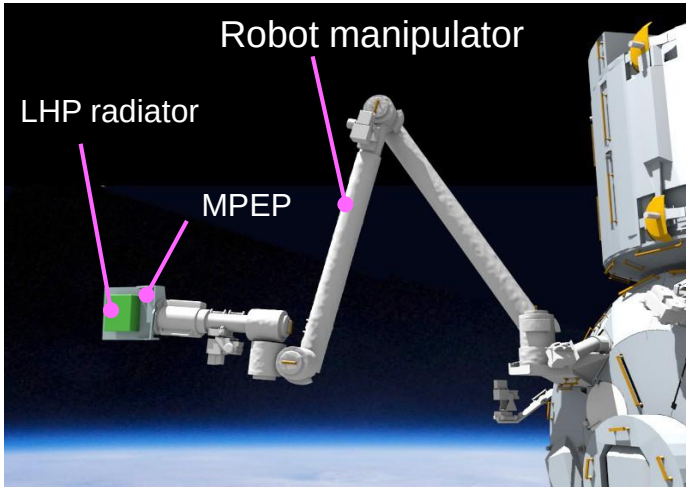
LHP showed stable behavior in sudden change in condenser sink condition.
Operating temperature increase 6degC when condenser sink temperature increased 25degC.

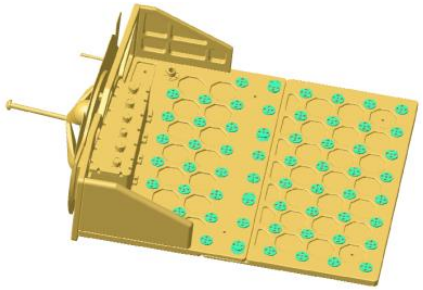
On-orbit experiment test plan

- On-orbit experiment of LHP radiator on ISS is planned.
- Experimental apparatus (LHP radiator) will be installed on the adaptor (MPEP, Multi-Purpose Experiment Platform) which is hold by robot manipulator of JEM.



Exposed pallet of ISS/JEM

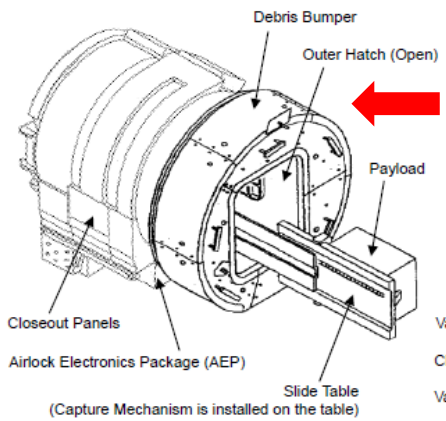


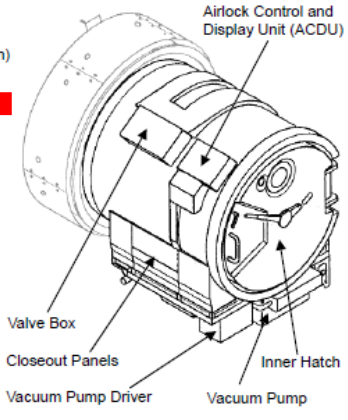


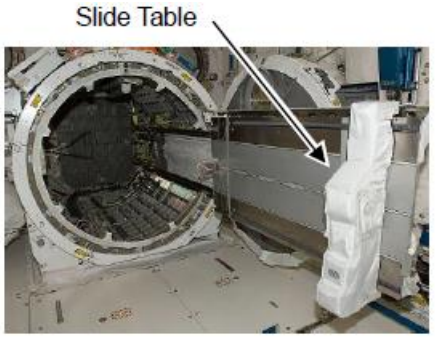
MPEP (Multi-Purpose Experiment Platform)

On-orbit experiment test plan (Cont.)

◆Launch scenario



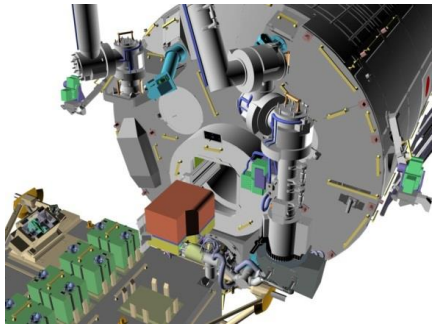




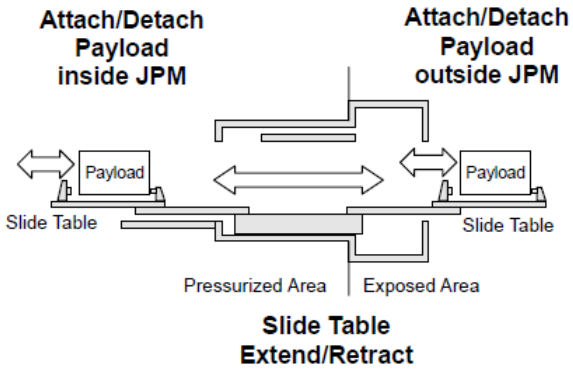
[②Attach MPEP onto Airlock]

[④Open outer hatch]

[③Close inner hatch]



[⑤Grapple MPEP by JEMRMS]



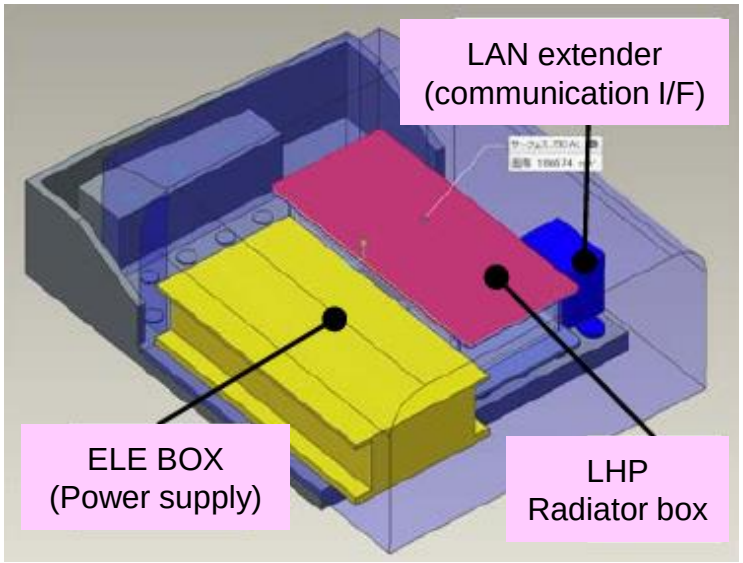
[①Launch in pressurized Cargo]

On-orbit experiment test plan (Cont.)

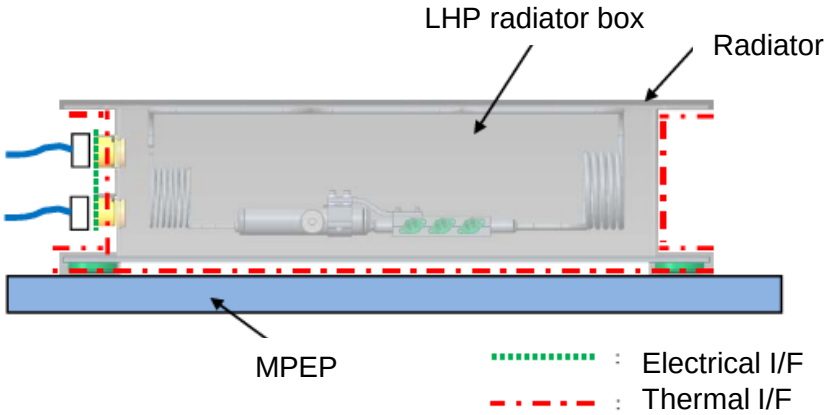
◆LHP radiator for on-orbit experiment

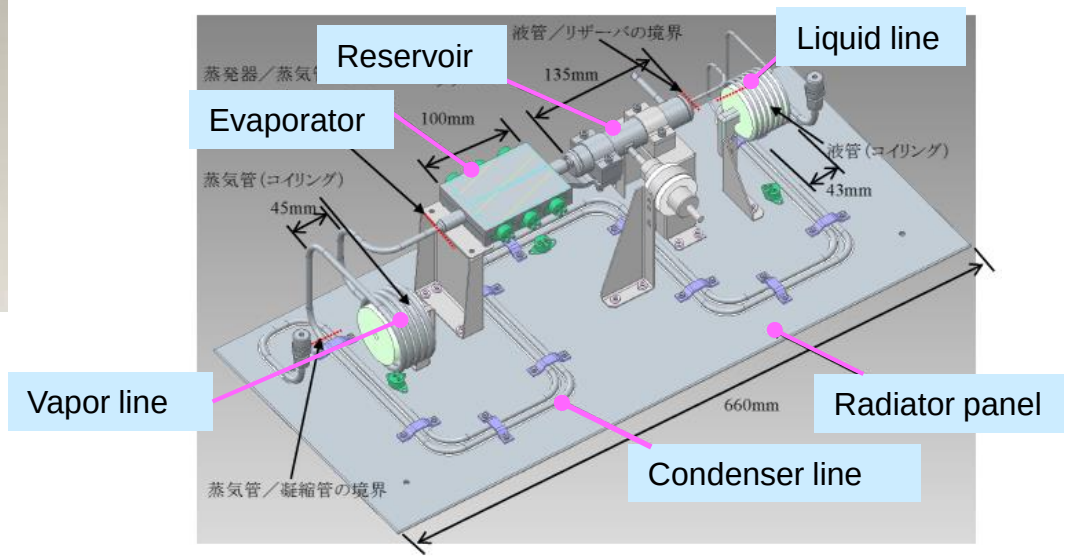
Design and fabrication have been conducting based on the BBM development

- Working fluid: Propylene
- Maximum heat load: 50W
- Heat transport length: 1.5m



LHP radiator on MPEP





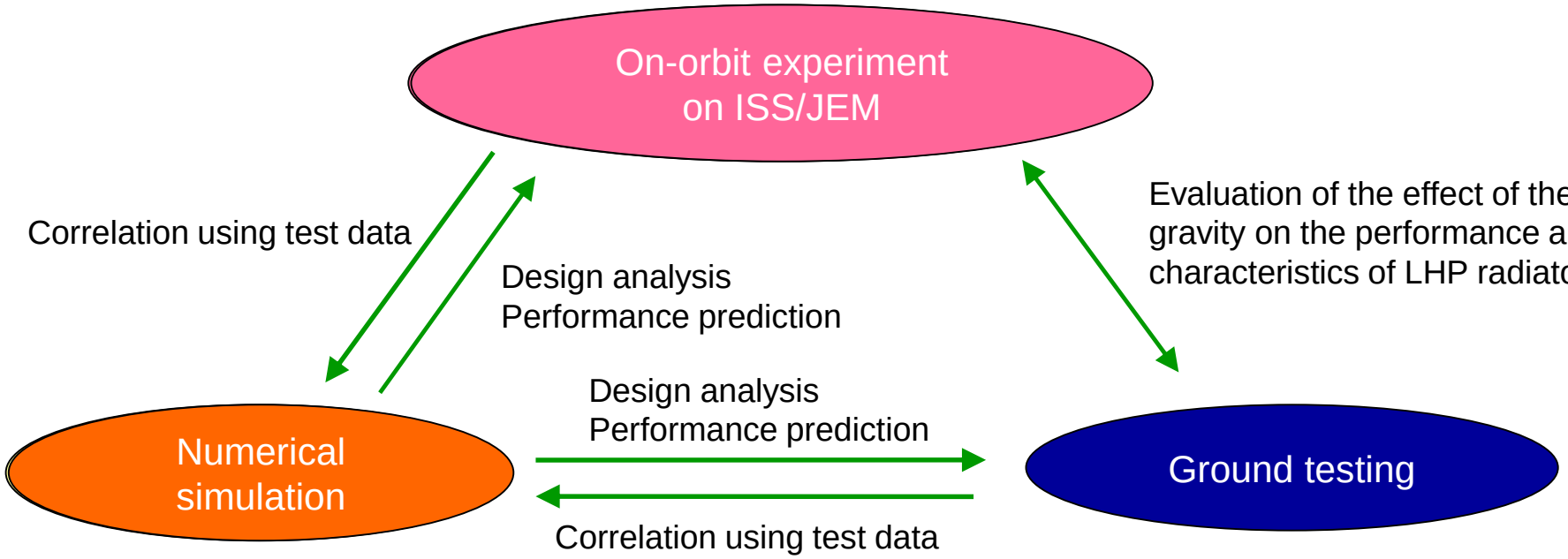
LHP radiator for on-orbit experiment

On-orbit experiment test plan (Cont.)

Technology demonstration in a mutual complement of following activities;

- On-orbit experiment on ISS/JEM
- Ground testing
- Numerical simulation

Part of this study will be conducted in collaboration with Nagoya Univ.



Technology demonstration plan of LHP radiator for application to space

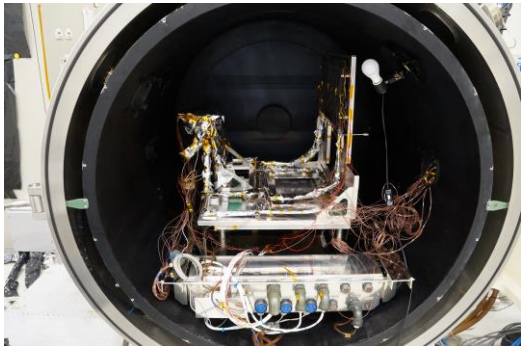
Development of PFM has been conducting. It will be launched in winter of 2016.

Summary

Overview of the development of LHPs in JAXA was introduced.

- BBM was designed and fabricated based on the technology which was acquired through the fundamental studies.
- BBM showed good performance as a result of the ground testing in ambient.
- Preliminary test plan for on-orbit experiment of LHP radiator was introduced.

Evaluation test in vacuum chamber was carried out.
As a result, BBM showed good performance also in vacuum condition.
The development of PFM for on-orbit experiment is now underway.
LHP will be launched in winter in 2016 by HTV, Dragon, or Cygnus spaceship.



Thermal vacuum test of BBM